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METHODS OF WASHING SLOW SAND FILTERS

BY JOHN GAUB[1]

In late years various processes for cleaning the sand of a filter bed have been advanced; some partly destroying and others exterminating the filter film on the bed. These ideas have in some cases caused trouble and in others only repair. There is no doubt that the rough treatment of the sand surface, a penetration of organic matter and filth into the bed cause deep clogging, which prevents the yield of water, and causes the beds to become inefficient.

Attempts to reduce the work of cleaning filters are commendable, because scraping, sand handling and raking are the items of greatest expense in slow-sand filter maintenance; hence it is the endeavor of the writer to show what attempts along this line have been made, both from an economical and efficient standpoint.

In this country it is bad economy to discard the sand scraped from the filters, for the expense attached to the preparation of new sand is very high, since it must be washed free from clay and screened before it is ready to be placed in the filter. Yet in Osaka, Japan, the sand is dredged from the Yodo river opposite the water works, and made suitable for the beds and placed therein for about 65 cents per cubic yard, a figure so low that no attempt is made to recover by washing the sand scraped from the filters.

In handling the sand for slow sand filters several methods have been tried, each giving results at a small cost in some places, while in others the contrary is true. The writer, therefore, compiled tables from plants using these methods, together with their costs. However, before delving into the methods as practiced at the various plants, a brief description of the methods commonly used will not be out of place.

THE BROOKLYN METHOD

This method was first used in 1905 at the Hempstead filters, at Rockville Center, Long Island, and consists in lowering the water to

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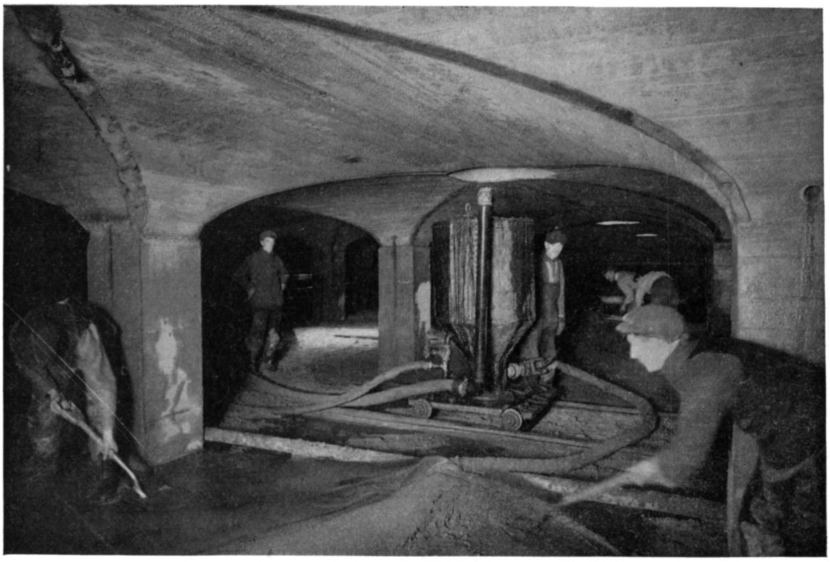
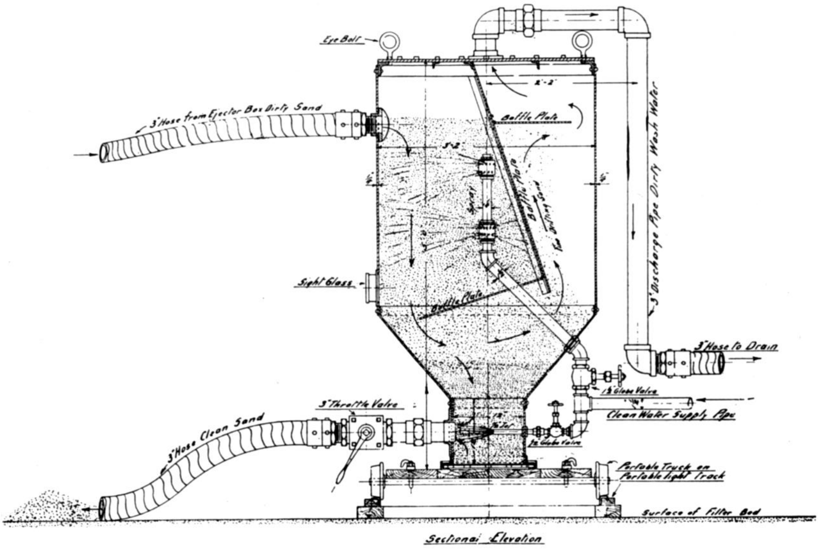
[1] Supt. Filtration Plant, Washington, D. C.



SAND WASHER IN USE AT TORONTO, CANADA



PORTABLE SAND WASHER IN USE AT TORONTO, ONTARIO, CANADA a few inches in depth above the surface of the sand on the filter. Unfiltered water is taken from an adjacent filter in service and run in a stream over the bed to the outlet drain, a depth of about 1 inch of flowing water being maintained over the section to be cleaned. Men in boots agitate the surface of the sand with long-toothed garden rakes, thus stirring the dirt from the sand and having it carried away to the drain. The filter is generally cleaned in sections by cutting off the part undergoing cleaning from the rest of the filter by boards set on edge and driven down into the sand, forming a miniature flume with board sides. After cleaning, the boards are removed to a new position. When the filter is clean, filtration is resumed. This method is somewhat costly, in that about 1 per cent of wash water is used. In cases of emergency it has given good results. At Philadelphia, it is reported that with 14 men and a foreman a three-quarter acre bed can be cleaned in eight hours and that such a bed will be out about nineteen hours a month.

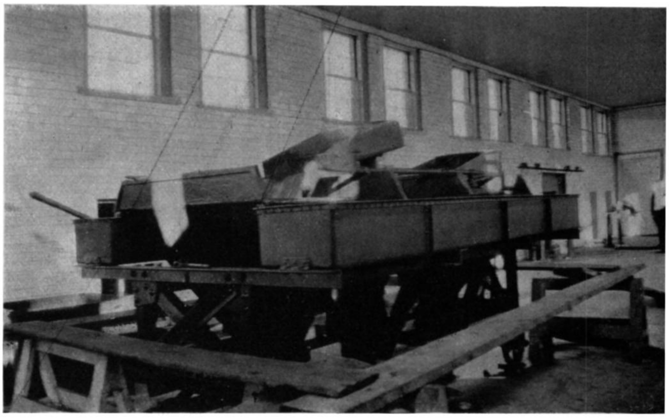
SAND WASHING MACHINES

These machines are recent additions to the washing apparatus used in slow sand filters. They began their existence about 1909 when the Washington plant adopted the "ejector washer" system. Previous to this time the dirty sand, after being scraped, was shoveled into portable ejectors on the beds, to be thence forced by water pressure through pipes to stationary sand washers. After being washed, the sand was discharged into storage bins, from which carts driven underneath may be loaded, and the sand carried to the filter and placed.

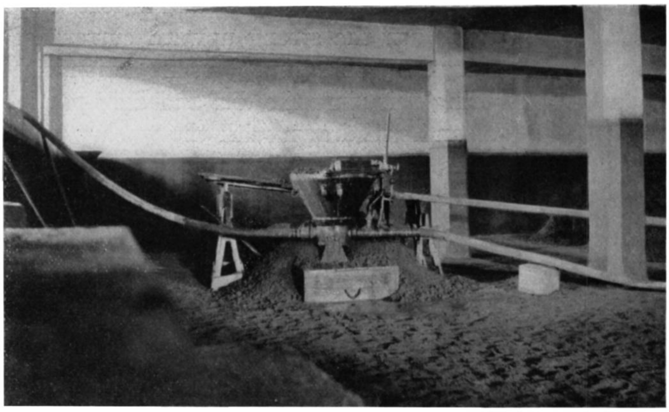
THE BLAISDELL MACHINE

This machine may be described as a traveling crane spanning a filter unit and supporting a watertight rectangular chamber containing the machinery necessary, and provided with means for lowering this chamber to the sand surface and traveling over the filter while the process of washing is in progress. The chamber wherein the washing takes place may be raised so as to clear the rim of the filter and thereby remove the machine to another filter.

About 2 inches above the sand or bottom of the sand chamber there is a plate or diaphragm dividing the washing chamber into two compartments placed above each other; the lower, used as a suction chamber from which the dirty wash water is withdrawn, contains



Sand Washer at New Haven, Connecticut

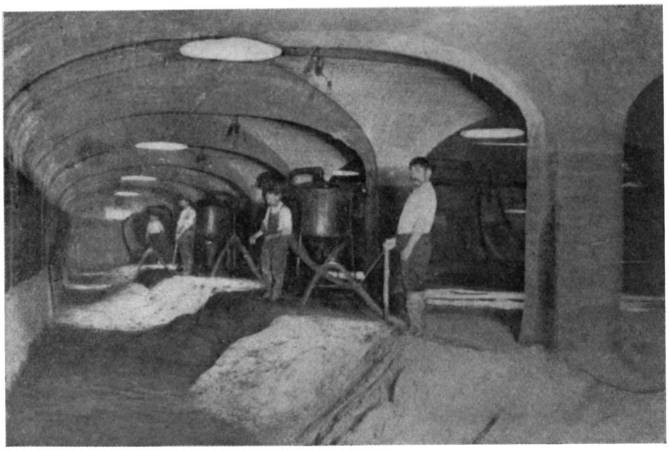


Hopper Sand Ejector at New Haven, Connecticut stirrer wheels mounted on vertical shafts; the upper contains the driving mechanism for the stirrer wheels and also the pressure and suction pumps.

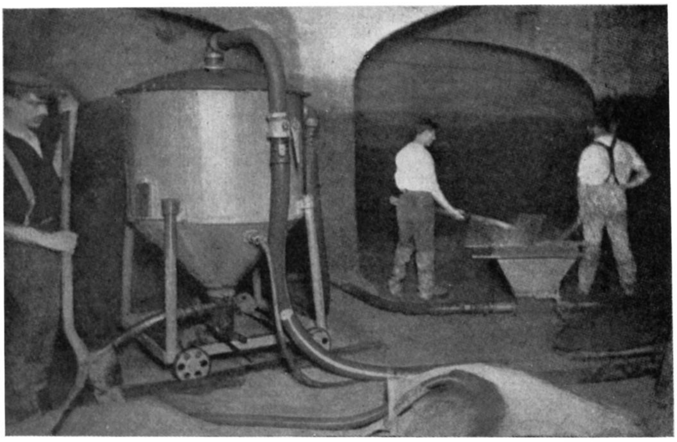
From the stirrer wheels, in the lower chamber, supported on vertical shafts above the sand, numerous teeth project into the sand to any desired depth. The teeth are hollow and perforated in order to create a water jet action from the supply delivered by the pressure pump. The water for the pump is taken from the water on the filter, while at the same time a suction pump joined to the top chamber withdraws not only all the water the pressure pumps supply through the perforated teeth, but also an additional amount from the filtered water in the sand. In operation, the teeth scour the sand, while the wash water by its jet action drives the dirt into the suction chamber and the clear water stored in the filter bed is drawn into the washing zone by the excess suction over the pressure supply, and the wash water is pumped from the supply before the machine passes a given point. The chamber is placed close to the surface of the sand by shoes extending in advance and to the rear of the front end back plate, while the side plates cut down into the filter sand.

The pressure water rises through the disturbed sand zone and is displaced by the inrush of clear water, the upward current of which occurs well toward the center of disturbance created by the teeth and covered by the suction chamber. The sand is forced apart by the teeth, and as they return the strong upward current of wash water causes a temporary suspension and churning action within the suction chamber. During this time the dirt and light particles are brought to the surface and withdrawn with the wash water. The sand in suspension settles after the violent upcast subsides, so that when the sand comes to rest it is uniformly water packed and free from air. The wash water from the machine is discharged to a gutter formed generally in the party wall between filter units. The wash water may be so controlled that sizing may be done by working all very fine sand to the surface and removing that which is too fine from the filter. This sizing is done by increasing the duty of the pressure and suction pumps so as to secure a downward velocity by which to hold the sand in suspension.

All of the operations of this machine are controlled by separate motors which are operated from a platform. Generally there are six motors mounted on the machine with variable speed controllers, With this machine it is possible to wash a bed of an acre in about



Replacing Sand Machine at Torresdale



Replacing Sand by Machine at Torresdale

twelve hours, and in about fifteen hours the bed can be in service, allowing three hours for closing valves, etc.

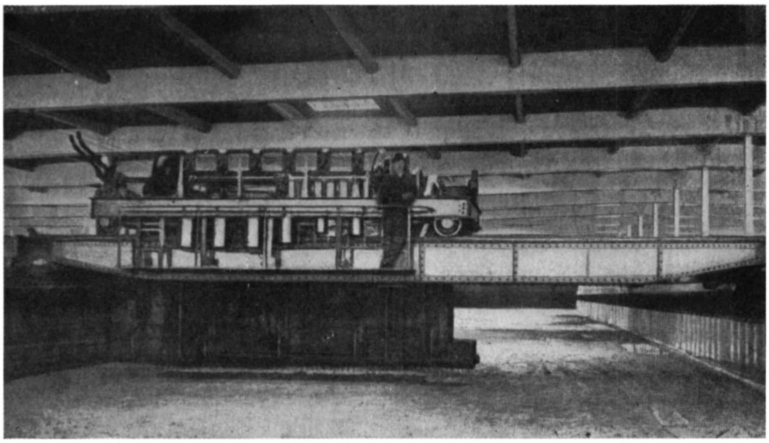
THE NICHOLS WASHER

This machine has been in use since 1910. It enables the operator to wash the sand on the filter without removing it from the bed, thereby saving not only in wash water, but also in labor, etc.; in other words the total saving being about 35 per cent of what it would cost to use the old method of scraping, removing, washing and replacing the sand. Briefly, the machine consists of an inverted cylinder inside a closed jacket. The dirty sand is fed into ejectors in the usual way, and the wash water with the sand and dirt passes through the machine. The water strikes the side of the cylinder, and the sand being heavy drops to the bottom and passes through a nozzle on to the filter. About 2 per cent of fine sand passes out with the water and dirt to the court where it generally settles while the débris goes to the sewer. It has been shown at some places that it is possible to clean 10 cubic yards per hour using 1200 gallons of water per cubic yard, whereas by the old method 2800 gallons of water were used. Again, at some places this machine has been modified, in that several sprays of water play on the sand within the machine; also more baffles have been added, thus causing a better wash for the sand.

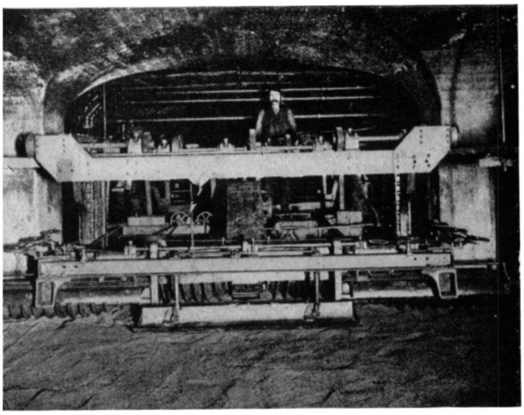
METHODS OF WASHING SAND AT DIFFERENT PLANTS

Washington, D. C.

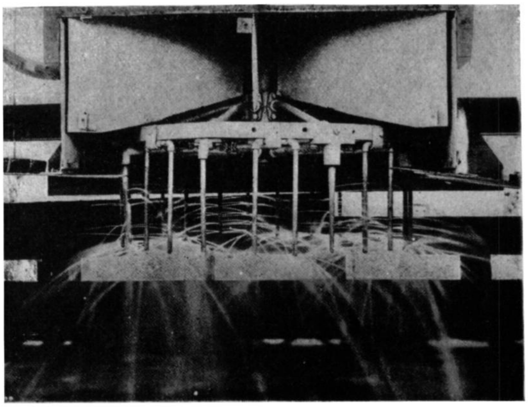
Until 1909 the filters were scraped and the sand piled, and then removed by ejector and one or more lengths of hose to the sand washers. After the sand was washed, it was discharged into storage bins from which carts were loaded and the sand brought to the desired place on top of the bed, and there dumped and spread evenly. After 1909 the hydraulic method of replacing was used, whereby an ejector is placed underneath the outlet gate in the storage bin, and the sand is carried in a reverse direction from the bin through piping and one or more lengths of hose to the bed. This process has decreased the cost of resanding and has proved very satisfactory in every way. This method has been used or tried in several places with more or less good results. At Washington the filters are resanded as follows: the filters are filled with water to the desired depth



Sand Washing Machine at Wilmington, Delaware



Sand Washing Machine Open, Showing the Different Parts



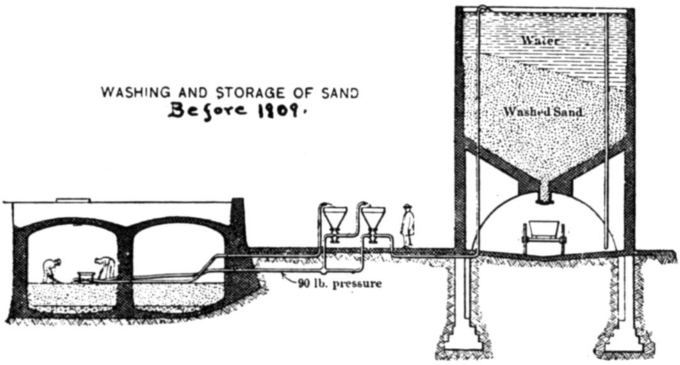
Sand Washing Machine Showing Jets

of the sand layer. The outlet end of the hose is joined to a 3 inch pipe supported on a boat, and the sand is discharged through the pipe at the point required. Generally work is begun at the far end of the filter, and is gradually filled by swinging the boat from side to side and backing it by degrees to the front end. By this method the sand has no tendency to separate into different sizes, if the discharge has a slope of about 40 to 45 degrees from the horizontal. By this position of the discharge pipe the old surface of the sand is cut and moved ahead with the new sand, thus breaking up the possibility of forming a mud layer between the old and new layers. The following is the average cost of scraping, ejecting, washing, transporting, replacing and raking.

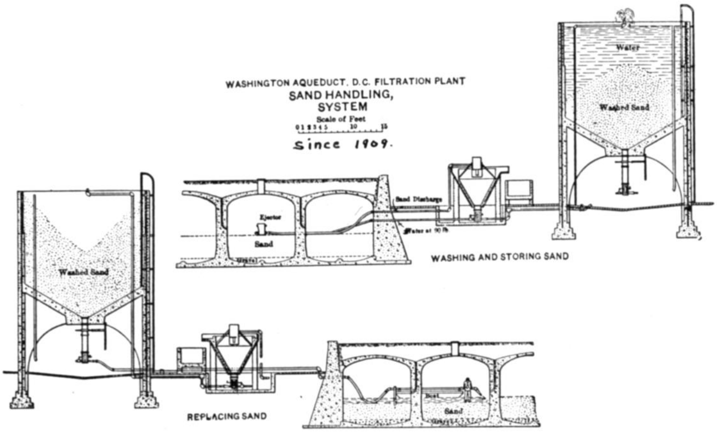
SCRAPING			RAKING		
Per cu. yd.	Per M. G.	Per acre	Per cu. yd.	Per M. G.	Per acre
$0.096	$0.07	$16.08	$0.042	$0.03	$6.64
EJECTING, WASHING AND TRANSPORTING			REPLACING		
.168	.11	28.32	.08	.06	

Sand Ejectors. The movable ejector is novel for two reasons: (a) The water for making the sand into suspension is brought up from the bottom and rises as the sand is shoveled into it, thus producing a mixture having more sand in proportion to water. (b) The discharge ends of the ejector are made like the discharge end of a Venturi meter, with a flat batter. The economy herein lies in the fact that use is made of the velocity head in the throat, which is lost with the batter made in the usual way. For a more detailed description of these ejectors and the tests whereby they were tested, the reader is referred to Vol. 57, 1906, of the *Transactions of the American Society of Civil Engineers.*

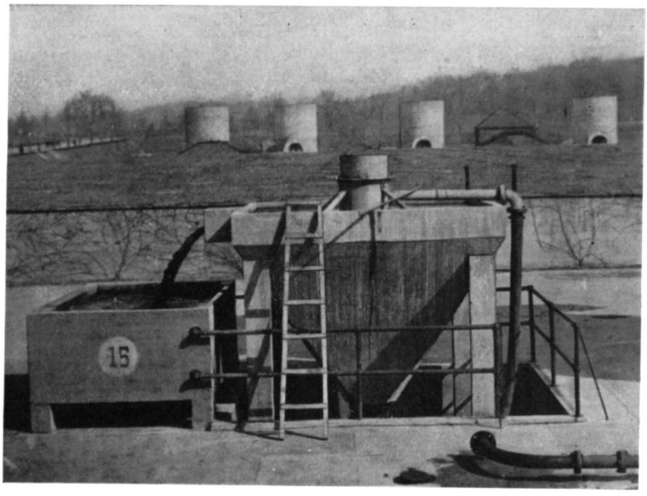
Sand Washers. The sand washer used here differs from the usual type of washer, in that the mixed sand and water fall into the hopper. From the hopper there is a free opening to a chamber formed by a globe casting. A second jet of water enters this chamber near the bottom, and is carried into the throat of the ejector with the sand as it leaves the hopper. The sand settles through the water into the chamber and is separated from all dirty water which came



Washing and Storing Sand at Washington, D. C. (Before 1909)



Washing, Storing and Replacing Sand at Washington, D. C. (Since 1909)



Washing Sand at Washington, D. C.

with it. The hopper usually used dilutes the dirty water in the sand, but the one devised at Washington makes a complete separation.

Toronto, Canada

Sand is washed by a portable washer. After being scraped in piles it is put into an ejector box from which it is carried to the washer. In the washer it passses through sprays of clear water, and by the action of baffles, falls to the bottom, where a strong spray drives it out through a hose, which distributes the clean sand on the filter. The wash water used is about $\frac{1}{3}$ per cent of the net yield of the filter. The wash water passes up to the top of the washer, then down to a 3-inch drain which connects with a 36-inch drain. The cost per cubic yard of sand, washed and replaced, including washer pump, handling sand, repairs, etc., is about $0.61.

Denver, Colorado

The sand is conveyed from the filters to the washer through an ejector and sand line of hose at a pressure of about 150 pounds. In this plant the ejector method of replacing was tried, but owing to stratification, was abandoned. The cause of stratification probably was a too high uniformity coefficient of the sand as it left the washer. The sand is replaced from dump cars, the cars being loaded by hand, hauled to the side of the bed by horse power, dumped, reloaded into side dump cars, pushed by hand to the place desired, dumped and spread. This is very costly, but owing to the thoroughness of mixing, it appears to be the best in the end. The total cost per cubic yard for cleaning and washing the sand on a bed is about $0.73.

New Haven, Connecticut

Here the water is drawn off and the sand piled, and wheeled to the hopper and carried to the washer by hydraulic means. From the washer the sand goes to a receiver in the bed having the lowest depth of sand, in which it is spread around and allowed to accumulate until the maximum depth of 40 inches is reached, when the apparatus is put into the next bed having the least depth. By this process about 5 cubic yards per hour can be washed, using about fifteen volumes of water to one of sand. The cost of cleaning per acre is about $75 not including the cost of water. About 60 cubic yards of sand are removed per cleaning, making the cost per cubic yard about $0.43.

Albany, New York

Up to 1910 the sand was washed and handled by the ejector method, but replaced by hand. In 1910 the Nichols machine was introduced and the cost of cleaning and replacing was reduced 44 per cent. However, there has been some trouble with the beds in this plant due to the formation of two filter-films caused by putting the new sand on the beds after forking the sand that remained there. The procedure of forking at the junction of ejected sand caused this film to increase until the turbidity of the sand ran 3–5000 and the output of the eight beds fell to 10 million gallons per day. However, the cost since 1910 to 1914 and 1899 to 1900 is as follows:

July 1899–1900

	per mil. gal.
Scraping	$0.25
Wheeling out sand	.50
Washing sand	.59
Refilling	.39

In 1910 a comparison was made between the Nichols machine and the box-sand washer with the following results:

Cost per cubic yard by box-sand washer	$0.409
Cost per cubic yard by Nichols	.226

Since 1912 and including 1914, the following is an average cost per million gallons.

Scraping	$0.07
Ejecting	.12
Washing and replacing	.16
Reforking beds	.01
Total	.36

Lawrence, Massachusetts

The sand is ejected to a set of three hoppers outside the bed. The sand from the last hopper is ejected to a large box having a weir which holds back the sand and permits an overflow of waste water. The sand is then shovelled out from the box down one of the ventilation holes for distribution on the bed. The cost per cubic yard is about 25 cents. It is claimed at this plant that the wheeling of the sand to the desired place and casting insures proper mixing, while the use of water pressure causes stratification due to the uniformity coefficient of the sand.

Pittsburgh, Pennsylvania

This plant has tried scraping, raking and washing machines. However, it appears that they are somewhat expensive, since the last four years, 1911–14, the hydraulic method was used and adopted. In the reports this method is known as the "Washington Method." The following summary gives an idea of the average cost.

SCRAPING			EJECTING	
Per cu. yd.	Per M. G.	Per acre	Per cu. yd.	Per M. G.
$0.175	$0.314	$25.42	$0.254	$0.450

RAKING			RESTORING SAND	
Per cu. yd.	Per M. G.	Per acre	Per cu. yd.	Per M. G.
$0.061	$0.064	$8.90	$0.087	$0.147
WASHING AND TRANSPORTING				
.120	.213	17.52		

Philadelphia, Pennsylvania

At Torresdale, the sand washing pumps had not been installed at the time of starting the plant, so another method of washing was resorted to, viz: the Brooklyn, as described above. This method was used until March, 1908, with little success, due to the sediment, organic matter, and micro-organisms forming a paste-like layer extending about 4 inches in depth. The consistency of the filter film was so at times that it could be removed in cakes. The runs were short and after about 100 million gallons had been filtered spading was tried in order to get the water through the filters. By this process, the surface of the filter was gone over with a spade and thrust down to a depth of 8 inches, and worked back and forth to break the layer. This caused an increased drop in efficiency with little assistance in length of runs. Next, the piling method whereby the sand is piled, waiting to be washed at some future time, was adopted, and it gave good results.

About 1909 Mr. Nichols designed a machine which today is used very much, by which it is possible to save 25 cents per cubic yard in sand handling. The advantage of this machine is that the thickness of the filter is not reduced while the danger of breaking through is decreased, and the efficiency not affected by the change in the rate of each filter. At this plant raking is practiced to the extent of two or three times per scraping. The following is a summary of the costs of the various methods used at Philadelphia:

REMOVAL		PILING	BROOKLYN	RESANDING
Per M. G.	Per cu. yd.	Per M. G.	Per M. G.	Per cu. yd.
$1.46	$0.43	$0.58	$1.68	$0.26
NICHOLS		RAKING	SPADING	
1.22	.41	.12	.38	

Springfield, Massachusetts

The methods used here are practically similar to those used at Washington, D. C. The following is a summary of the costs:

	M.G.
Cleaning	$0.36
Resanding	.17
Raking	.09

Wilmington, Delaware

At this plant a very good example of the Blaisdell machine is seen. The machine is used for raking and washing the sand on the beds. It was expected that the cost of sand washing, etc., would not be greater than one dollar per million gallons. However, since the plant requires intelligent superintendence at all times, and skilled mechanics for operating the washing machine, and notwithstanding that the machine is idle about 70 per cent of the available working time, the cost has been a little over the expected cost. The following summary gives an idea of the requirements of the machine together with the costs.

Average kw. per bed	115
Cost of kw. per bed	$3.45
Total cost per M.G	1.23

The total cost per million gallons is an approximate sum, but the other figures are averages for the years 1911–14.

YIELDS

Having considered the methods for washing the sand of the various slow sand filters, it now becomes our duty to consider the different methods as to yields.

Philadelphia, Pa. (Torresdale)

1907–12 (SUMMARY)

Yield, million gallons					Days run		
	max.	*min.*	*av.*	*rate*	*max.*	*min.*	*av.*
Brooklyn	67	4	19	1.8	49	6	14
Removal	379	10	74	3.6	105	4	27
Nichols	569	30	150	4.4	148	11	45
Rake 1	280	3	85	4.7	75	2	24
Rake 2	120	17	52	4.6	31	6	15
Rake 3	73	17	41	3.9	24	5	14
Piling	167	3	35	2.6	19	2	18
Spading	90	11	51	4.5	22	4	15

Washington, D. C.

	AV. NUMBER OF RUNS ENDING		DURATION IN DAYS (AV.)		AV. MILLION GALLONS FILTERED		
1905–10	143.4		66		170.13		
	Rake	Scrape	Rake	Scrape	Rake	Scrape	Total
1910–14	75.5	84.2	56	68.5	119.87	150.24	270.11

Springfield, Mass.

1913	23	22	44	48	79.08	98.29	177.37
1914	24	26	40	44	77.15	84.64	161.79

Wilmington, Del.

	PER CENT TIME OUT	DAYS OPERATED PER WASH	YIELD PER WASH	YIELD PER RUN
			M. G.	M. G.
1911–12	2.10	13.4	14.127	24.372
1912–13	3.0	20.5	9.817	39.877
1913–14	2.3	23.8	7.133	45.648

From these tables it will be seen that each method has its advantages and disadvantages. The Blaisdell machine is very economical in that the time in which a filter is out is practically at a minimum; however, the days in which the filter is operated after the wash are somewhat at a minimum also. As for total yields the processes as practiced at Washington and Torresdale appear to show up better. However, from a standpoint of duration in days the Washington methods are the best and cheapest.

CONCLUSIONS

From the experiences at the various plants cited it is seen that much improvement in sand handling has been in progress, especially in building machines.

The cost of cleaning a filter by machine has not been reduced below that for cleaning and replacing sand by the improved hydraulic processes.

The uniformity coefficient of the sand is an important factor to consider when hydraulic processes are used.

The hydraulic processes as practiced at Washington and Springfield are the cheapest and most economical.

ACKNOWLEDGMENT

The writer is indebted to all those who have given him data regarding their respective plants; also the New England Water Works Association for the cuts on the Nichols machine at Torresdale; this Association for the cut on the Blaisdell machine at Wilmington, Delaware.